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Sustainable vineyard floor management: An equilibrium between water consumption and soil conservation

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Abstract

Sustainable vineyards soil management can help to mitigate the negative effect of intensive agriculture on soil ecosystem for the achievement of the sustainable development goals. Cover crops use as cover management in vineyard could be considered as nature based solution for soil restoration and proper water management. Cover crops (CC) provide many ecosystem services through carbon sequestration and climate change regulation, water purification and soil protection. However, a holistic approach is needed to understand the maximum potential ecosystem service that can be provided in different soil and climatic condition also considering vineyard needs. The current knowledge of CC management on soil erosion, water content and soil C sequestration in flat and slope field is reviewed. Results of this analysis suggest that the sustainable intensification, due to alternative vineyard soil management, could represent a strategic option for nature based solution but, contemporary, tactical choices must be taken into account to obtain a real environmental, social and economic benefit. Further studies are necessary to correlate the environmental factor (climatic characteristic), hydraulic properties and management (CC species, type of CC) with the global ecosystem service of CC management in economic and environmental terms, in order to provide for each environment clear guidelines. This step could be important to favour the spreading of CC in vineyard as a proper strategic management.

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Cover crop, Vineyard, Soil erosion, Water budget, Soil organic carbon, Slope.

Introduction

Degradation of agricultural soils, mainly due to sediment erosion and nutrient decline, contributes to a reduction of plant vigour, yield, biodiversity, economic and environmental sustainability [1–4]. Soils of drylands areas and Mediterranean regions are highly susceptible to degradation process because of topographical and climate characteristics. In agriculture land, soil degradation is exacerbated by human impact through crop and floor management. In order to preserve natural resources, the global policies are promoting alternative and conservative soil agriculture practices. Borelli et al., [2], for instance, estimated a reduction of soil erosion of 7% through the introduction of conservation agriculture in comparison to the baseline scenario of 2012.

Vineyards in Mediterranean basin are strongly degraded with low level of organic matter and biodiversity due to the intensification of agricultural practices, which entailed the removal of cover vegetation that is considered a cause of yield reduction [5–7]. In particularly, vineyards in sloping areas are responsible of accelerated soil loss and surface water contamination due to continuous tillage and lack of soil cover for almost the whole year [8–12]. Consequently, the use of cover crop as alternative cover management to conventional tillage spread, especially in temperate winegrowing regions or in irrigated vineyards. Cover crop has multifunctional benefits on soil, including erosion control, soil structure improvement, nutrient retention, easier mechanisation, biodiversity increase [13–16]. Although the numerous well-known benefits of cover crop on soil ecosystem services, the widespread in semiarid region is weak due to probably water competition with vines [17]. While in temperate environment cover crops have been widely recommended to reduce the excessive water or soil nutrients, which can lead to an exorbitant vigour of vines [18–20], in arid and semiarid climate, the water lost by cover crop consumption can be a risk for yield reduction when the annual precipitation is lower than 1000 mm [21]. Despite several studies have highlighted the negative effect of CC due to water consumption in flat semiarid environment, there is a lack of results to evaluate the complete water budget in sloping vineyard, also considering the ecosystem service benefits on soil erosion control and CO_2 emission reduction [22]. Some aspects, such as the effect of slope on CC benefits assessment, could lead to significant disagreement with the actual point of view which highlights the negative impact of CC in semiarid environment. Hence, it is

necessary to have an holistic approach on the effect of CC which takes into consideration the relation among soil resources, organic carbon stock, water budget in relation to environmental characteristics.

Cover crop and soil resource

Cover crop has a noteworthy effect on soil erosion control, reducing sediment loss in comparison to conventional tillage [23]. Novara et al., [23] founded a reduction of erosion with CC ranging from 40% to 76% in comparison to conventional tillage (CT), while other authors recorded reductions highest than 90% [24,25]. The losses of sediment and nutrients in runoff are reduced by CC through reduction of raindrop energy and runoff velocity; improving, in the long term, soil organic matter, soil aggregate stability and water infiltration. The magnitude of the effect of CC on erosion control is influenced by CC species. As an example, Novara et al., [23] comparing different CC species in the same environment founded the highest erosion rate with *Vicia faba* and the lowest one with a mix of *Vicia faba* and *Vicia sativa*. The effectiveness of CC species on soil erosion control depends by biomass yield, root systems, speed of emergency and uniformity which determine the percentage in time and space of soil cover [23].

The effectiveness of CC in erosion control is, moreover, affected by slope gradient and consequently the magnitude of the benefit on ecosystem services (Figure 1a). Galati et al., [26] estimating the ecosystem service in economical term of CC management using the replacement cost method, showed that ecosystem service increases with the slope and the payment for ecosystem service to subsidize alternative soil management practice should be performed in relation to topographical aspects. The relevance of slope gradient factor in soil erosion evaluation studies was highlighted in a research carried out by Corti et al. [27]. They compared two vineyards with different slope, managed with grass cover in the inter row, finding that erosion was reduced by CC in soil with a slope of 15%, while no difference was founded in 5% slope [27].

Cover crop for erosion control, therefore should be highly recommended in high slope vineyard, paying attention on the best CC species.

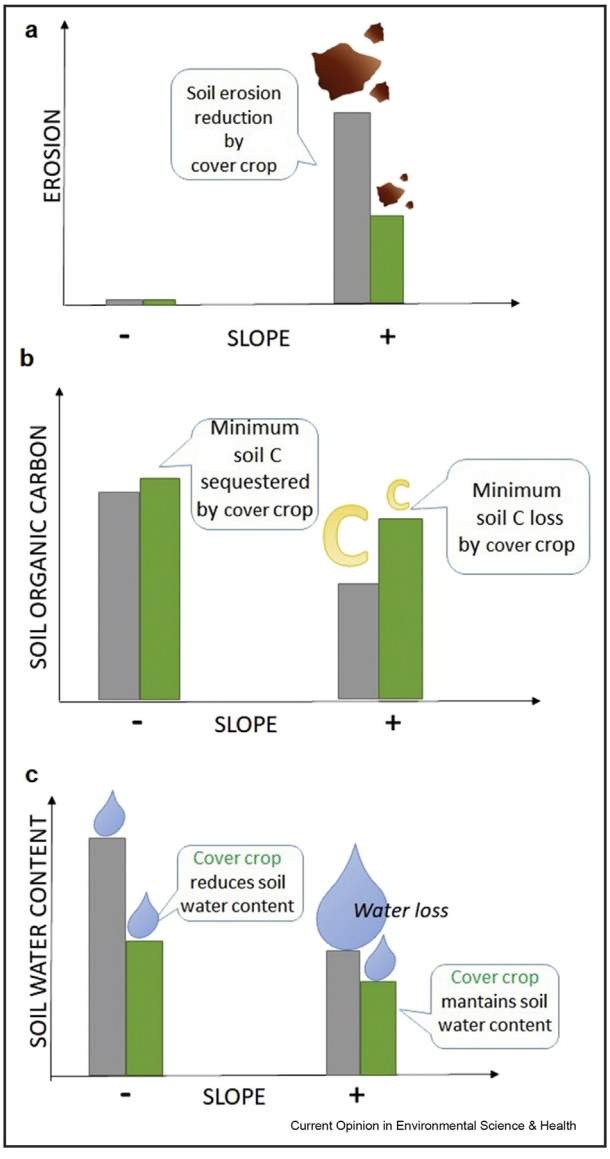
Cover crop and organic carbon

Soil management which favour the restoration of soil organic matter increases the agricultural system sustainability. The increase of soil organic carbon contributes to CO_2 mitigation, reducing the impact of agricultural on climate change; moreover, the benefits of organic matter on soil, such stabilization of soil aggregate, water and nutrient retention, biodiversity increase, allows to reduce the use of external inputs (i.e. fertilization, tillage) [28–31].

Considering the C budget, CC floor management can contribute to increase the above and below C input [32]. The magnitude of this effect is noteworthy different in relation to CC dry biomass, species, C/N ratio, duration since CC application and especially soil and climatic parameters [33].

The benefit of CC on SOC sequestration was mainly recorded in the first layer of vineyard soil by some authors [34–36], while other authors recorded no significant increase after CC application in SOC stock [37,38] or a new steady-state level achievement after few years [39]. The limiting condition in semiarid environment

Figure 1



Schematic representation of the effect of cover crop (green histograms) versus conventional tillage (grey histograms) on soil water, soil organic carbon and soil erosion in flat and sloping vineyards.

(water availability, degraded and poor soil) and unfavourable climate contributes to low C sequestration rates.

Differently, in slope position the difference between SOC stock between CT and CC management could be higher due to action of nutrient retention and decrease of OC loss associate to sediment (Figure 1b). Therefore, the magnitude of CC benefit on C sequestration should be evaluated according different condition, but particular attention should be payed to topographical aspect [40].

Moreover, further studies should be carried out to analyse the effect of CC on long term; the new management could need some years before to reach a new equilibrium.

Cover crop and soil water

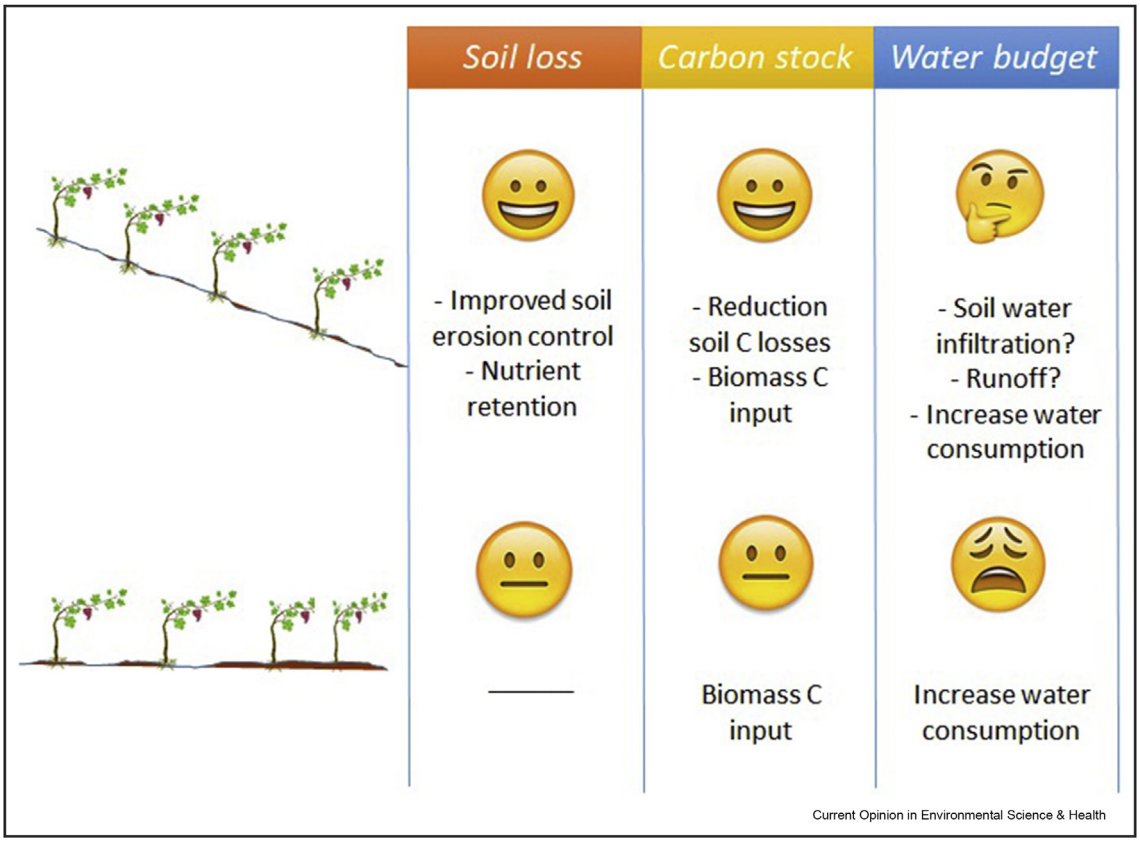
Water content is one of the most constrain for yield in semiarid vineyards and this was the main reason that has discouraged farmers to use cover crop, especially under rainfed crops. Several studies recorded that CC interferes with vine for water resources with a consequent increase of vine water stress [41–44]. On the contrary other research has been shown no difference in water stress between vines under CC and CT [19,45]. The competition between vine and CC could be also have a positive effect on vineyard as shown in southern Portugal by Tomaz et al., [46]. Their findings showed that over time, the CC leads to the smaller root of vine to explore deeper soil layers to seek water.

In slope fields, some studies recorded an increase of soil water content in olive groves managed with CC in comparison to bare soil, due to the increase of infiltration rate which was correlated to rainfall intensity [47,48]. The ability of CC to increase rainfall infiltration rate and therefore to store more soil water is mainly relevant in region where rainfall are concentrated during winter period with high rainfall events. Therefore, CC can be a risk for grape yield in flat area due to increase of water competition in comparison to bare soil, while it increases the water storage in slope fields in comparison to CT (Figure 1c).

Conclusions and recommendations

The analysis of the effect of cover management in vineyard on soil, water and carbon resources and balance showed contrasting results on the benefits of CC in comparison to CT. Since, very few studies analysed

Figure 2



Ecosystem service value on water, soil and carbon resources provided by cover crop in comparison to traditional management in flat and sloping vineyard.

contemporary the equilibrium among water budget, soil and sediment resource, the overall analysis of the CC benefit in semiarid environment remains uncertain and further research are necessary. To evaluate the ecosystem service provided by CC management on water, carbon and soil, limiting factors and environmental characteristic should be considered together with vineyard needs in terms of water, nutrient availability and soil habitability. The results of this analysis on C stock, water content and erosion control, showed that the overall effect of CC could be both negative and positive in relation to topographical aspect (Figure 2). In sloping vineyard CC are effective to reduce soil erosion and nutrient loss. The control of soil erosion leads to a high Carbon sequestration rate which is determined by the new C input from CC species and by the reduction of C losses by water erosion. Moreover, in slope vineyards, the CC mitigates the water consumption of CC species with the increase of water infiltration. In flat vineyards, the effect of CC is less evident in comparison to sloping terrain ones. In fact, there is no effect on soil erosion; the carbon stock usually increases slightly due to the new C input, while there is a negative effect regarding the water consumption due to the increase of CC species transpiration.

Hence, the probability of success on environmental sustainability improvement of CC in respect to CT is high in slope vineyards (Figure 2). In order to establish the overall effect of CC and provide useful guidelines on the risk evaluation of CC management on water budget and consequently grape quantity and quality yield, it should be necessary to establish an evaluation system to compare the gain or losses of different resources. Future researches should be addressed to assess the magnitude of advantages and disadvantages of CC management using a unique reference system to have a net balance of sustainability variation. More knowledge is, therefore, necessary to solve the following answered questions: i) which is the equilibrium between water consumed and sustainability increase considering the needs of a flat vineyard?; ii) Can the increase of water infiltration in a slope vineyard offset the loss by transpiration of CC species?; iii) Which is the threshold of yield loss in return of sustainability increase, that could be accepted by farmers?; iv) Which is the slope threshold under which CC use is unsuitable and/or unnecessary to achieve sustainability goals and *vice versa*?

Another weak point on CC evaluation is the consideration of long term effect taking into consideration the purposes of vineyard system. The management of CC as nature based solution is dynamic over the time and therefore the benefits may be appreciated only after a slow achievement of new ecological equilibrium status. The lack of collaboration of farmers to achieve a sustainable management is based in their negative perception of CC and other covers [41,49,50].

Conflict of interest

Nothing declared.

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